

IMPLEMENTATION OF LQR CONTROLLER ON COUPLED TANK LIQUID
LEVEL SYSTEM

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**Dedicated to my beloved parents, sibling and friends
For giving a constant source of support and encouragement**

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ABSTRACT

Coupled Tank system used for liquid level control is a model of plant that has usually been used in industries especially chemical process industries. Level control is also very important for mixing reactant process. The basic concept of how the coupled tanks system work in this project is by using computer as the main control where user can control the level of liquid in one tank or both tanks. To control the liquid level automatically, a controller is needed to be implemented. For this project, LQR controller is used. Advantech USB 4716 DAQ is a device use to communicate between computer and the computer. Basically, this project focuses on the design and modeling for coupled tanks system with the implementation of LQR controller. Mathematical model of the system is first taken from manual book provided by AISB Sdn. Bhd. and verified by MATLAB. Based on the simulation result, the value of state feedback produce by LQR is used in Visual Basic to see the response in real time process.

ABSTRAK

Tangki berkembar penyukat ketinggian cecair adalah satu model mesin yang biasa digunakan dalam industri terutamanya industri yang berasaskan pemprosesan bahan kimia. Kawalan ketinggian juga penting untuk proses campuran bahan bertindak balas. Konsep asas bagaimana untuk tangki berkembar berfungsi dalam projek ini ialah, dengan menggunakan komputer sebagai pengawal utama, pengguna boleh mengawal ketinggian cecair di dalam satu tangki atau untuk kedua-dua tangki. Untuk mengawal ketinggian cecair, pengawal mestilah digunakan dan untuk projek ini, pengawal LQR digunakan. Advantech USB 4716 DAQ adalah satu alat yang digunakan untuk komunikasi diantara tangki berkembar dengan komputer. Secara umumnya, projek ini tertumpu kepada mereka dan membuat model untuk tangki berkembar dengan penggunaan pengawal LQR. Model matematik untuk sistem ini diambil daripada buku manual yang disediakan oleh ASIB Sdn. Bhd. dan di buktikan melalui simulasi MATLAB. Berdasarkan hasil simulasi, nilai untuk maklum balas yang dihasilkan oleh pengawal LQR digunaknan untuk melihat tindak balas dalam masa sebenar.

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LIST OF SYMBOLS

DAQ- Data Acquisition

GUI- Graphical User Interface

LQR- Linear Quadratic Regulator

SISO- Single Input Single Output

MIMO- Multi Input and Multi Output

CHAPTER 1

INTRODUCTION

1.1 Overview

Control engineering is among the most theoretical and difficult to understand. In industries, application of liquid level control system is widely use especially in chemical industries. One of the liquid level control systems models that normally use is Coupled Tank liquid level system. This kind of system usually controlled using PID, Fuzzy logic control and other few more controllers.

The implementation of Linear Quadratic Regulator (LQR) on Coupled Tank liquid level system is one of the new methods of controlling liquid level and will be discovered in this project. LQR is one of the theory of optimal controls that operating a dynamic system at minimum cost.

Through this project, CTS-001, which is a computer controlled couple tank system, will be used with the implementation of LQR controller. Basically CTS-001 is a model that consists of coupled tank (CT-100), software developed using LABWINDOWS/ CVI environment and data acquisition card. CTS-001 is used for real-time experimentation such as for steady state error analysis, transient response and also controlling tuning method. [1]

The main aim of this project is to implement LQR controller on Coupled Tank water level system so that the efficiency of the system can be optimized. The method is to control the water flow into the tank 1 in corresponding to water level/height of water in the tank 2. This system is setup in second order system.

1.2 Problem statements

Real-time control involves algorithms to control a certain processes. In order to study its performance in terms of implementation in real-time and each control features, control of level of a coupled tank is chosen. This application is widely used in the process industry especially in chemical industries. In this project, controlling liquid level process will be done in real-time by applying Linear Quadratic Regulator as controller. A common control problem in process industries is the control of fluids level in storage tanks, chemical blending and reaction vessels (Grega and Maciejczyk, 1994). The flow of liquid into and out of the tank must be regulated as to achieve a constant desired liquid level as fluid to be supplied at a constant rate. Many control algorithms have been implemented using various techniques to compensate with the control requirement. Each of them has its own advantage and disadvantage. The most commonly use controller to control liquid level in coupled tank system is Fuzzy Logic Control and also PID. There are wide arrays of other control techniques that have been applied to meet the control objective of the system. Various factors are considered in designing the controllers such as set point tracking and load disturbance, reducing the effects of adverse conditions and uncertainty, behaviors in term of time response (e.g., stability, a certain rise-time, overshoot, and steady state 3 tracking error) and lastly engineering goals such as cost and reliability which is vital in industrial perspective.

1.3 Objective

The main objective of this project is to evaluate the performance of liquid level control with the implementation of LQR controller on coupled tank liquid level system. The second is to simulate LQR controller for water level control in MATLAB Simulink (Second-Order system). Lastly is to observe the performance comparison between experiment and simulation result.

1.4 Scope of Project

The scope of this project is:

1. To Implement LQR controller using Visual Basic 6 on Coupled Tank water level system.
2. Hardware
 - a. To install data acquisition card (DAQ).
 - b. To make sure that the coupled tank can work and can communicate with DAQ card
3. Software
 - a. To simulate the system using MATLAB
 - b. To study and Design GUI using Visual Basic 6

1.5 Summary

This section introduces the overall project and explains the objectives and also the scope of the project in order to give general overview of the project. In the next chapter will review on previous research that is related to the current work which concerns to LQR controller, coupled tank system, and direct digital control (DDC). Literature review is important as guidance to this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will review on previous research which concern to couple tank system, controller algorithm, linear quadratic regulator and direct digital control. There are numbers of control strategies and methods in controlling the liquid level in the coupled tank system which had been implemented by researchers will be reviewed in this chapter.

2.1 Coupled Tank

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries [1]. The process industries require liquids to be pumped, stored in tanks, and then pumped to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated. Often the tanks are so coupled together that the levels interact and this must also be controlled. Level and flow control in tanks are at the heart of all chemical engineering systems. But chemical engineering systems are also at the heart of our economies. Vital industries where liquid level and flow control are essential include:

- Petro-chemical industries.
- Water treatment industries

2.2 Linear Quadratic Regulator

The constrained LQR approach also removes what we consider in current MPC (model predictive control) approaches to be a nuisance tuning parameter, the control horizon N , i.e., the number of future control moves considered in the optimization [4]. The optimal Linear Quadratic Regulator (LQR) method is a powerful technique for designing controllers for complex systems that have stringent performance requirements. For most realistic applications, the LQR problem must be solved via a Computer-Aided-Design (CAD) package such as MATLAB. With the CAD packages solving the optimization problems, the challenge lies in how the weighting matrices are chosen [5]. There a few sample of application of LQR controller for example application of Linear Quadratic Regulator (LQR) in Displacement Control of an Active Mass Damper. In this paper an optimal displacement feedback control law is derived for a vibration control of a single-degree of- freedom structure with an active tuned mass .damper (ATMD). Analytical expressions of the linear quadratic regulator (LQR) feedback gains for the ATMD are derived by solving the Ricatti equation straightforwardly.

2.4 Direct Digital Control

Central controllers and most terminal unit controllers are programmable, meaning the direct digital control program code may be customized for the intended use. The program features include time schedules, set points, controllers, logic, timers, trend logs, and alarms. [3].

The unit controllers typically have analog and digital inputs that allow measurement of the variable (temperature, humidity, or pressure) and analog and digital outputs for control of the medium (hot/cold water and/or steam). Digital inputs are typically (dry) contacts from a control device, and analog inputs are typically a voltage or current measurement from a variable (temperature, humidity, velocity, or pressure) sensing device. Digital outputs are typically relay contacts used to start and stop equipment, and analog outputs are typically voltage or current

signals to control the movement of the medium (air/water/steam) control devices, usually abbreviated as "DDC".

Direct Digital Control (DDC) refers to the ability to control HVAC (sometimes referred to as "climate control") devices via microprocessors containing software performing the control logic. DDC receive analog and digital inputs from the sensors and devices installed in the HVAC system and, according to the control logic, provide analog or digital outputs to control the HVAC system devices [3].

2.5 Summary

Literature review has been presented in terms of different aspects. The first part that had been discussed is the Couple Tank and modeling of the system. Previous research using real-time software would ease the implementation for control objectives. Next, the algorithm chosen for this research (LQR) had been discussed to see its behavior and outstanding characteristics from prior implementation in industry and academic studies. This is important to know the current trend of the algorithm application. Finally, review about direct digital control (DDC) was presented.

CHAPTER 3

METHODOLOGY

3.1 Overview

The scope of this chapter is to provide further details of methodology and approach in completing this project. Level control is one of the control system variables which are very important in the industries. AISB Coupled-Tank Control Apparatus CT-001 serves as a low-cost pilot plant that represents the interacting tanks in the actual industries. The CTS-001 will be used for real-time implementation. Thus, system identification of non-parametric model is involved in modeling the system in Visual Basic. The model obtained is specialized to both tanks system (second order single input single output). The process plant, data acquisition card and the software will be discussed for its implementation throughout the project in this chapter.

Figure 3.1 show the flow chart of this project. The project progress is based on this flow chart. Basically, this project starts with problem analysis and after that, defining hardware and software. Then, it is dividing into two parts that is hardware and software. The hardware part include the coupled tank setup, Advantech 4716 USB DAQ installation or connection and also communication testing between Advantech 4716 USB DAQ with the coupled tank. For the software part, the process include installing Visual Basic 6, modeling the system in MATLAB, designing GUI in Visual Basic 6 and as well as programming and testing.

At the end part of this project, the hardware and software is integrated and the troubleshooting process is done. The flow of this project is shown in figure 3.1 below.

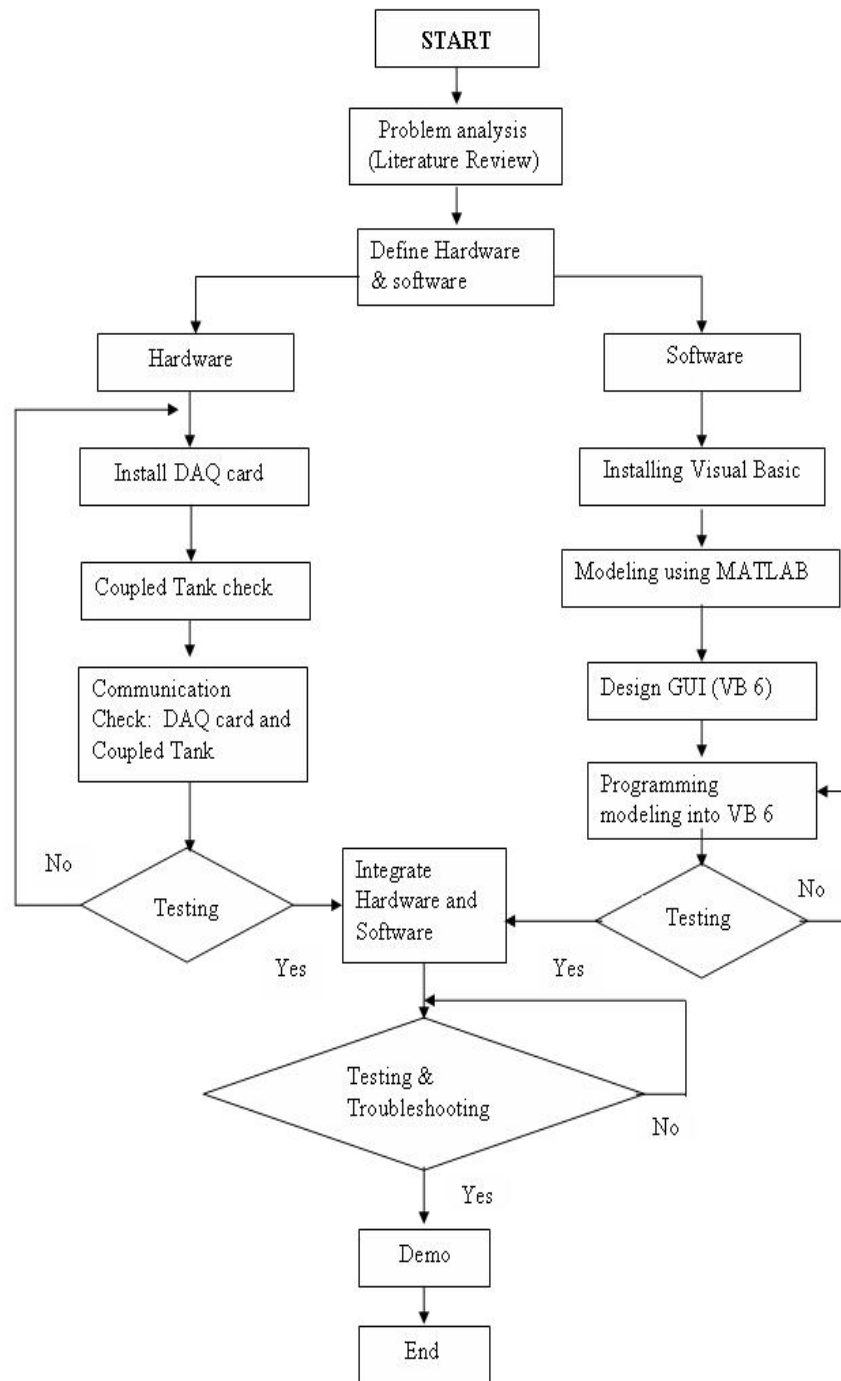


Figure 3.1: Flow Chart of the project work flow

3.2 System Identification

Basically the Coupled System is setup in second order single input and single output (SISO) system. Figure 3.2 is the block diagram of an open loop system (second order SISO) and Figure 3.3 is block diagram of an open loop system (second order SISO) with LQR controller.

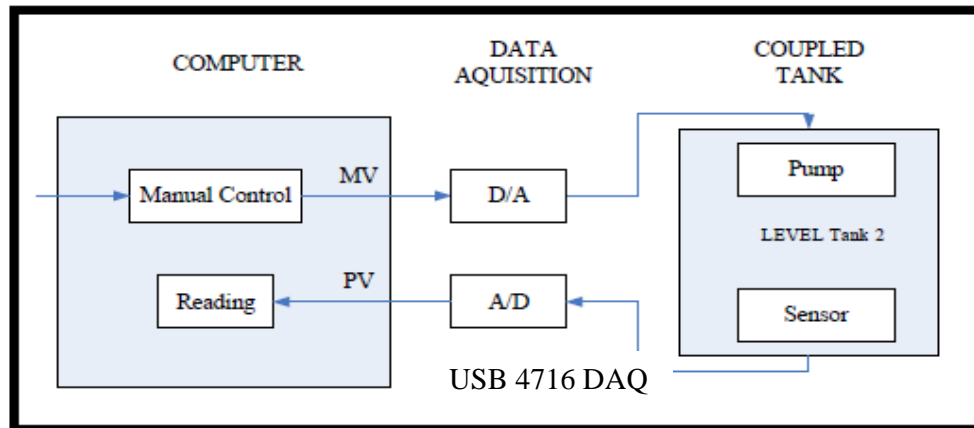


Figure 3.2: Block Diagram of open loop system (Second Order SISO) with USB 4716 DAQ interfacing

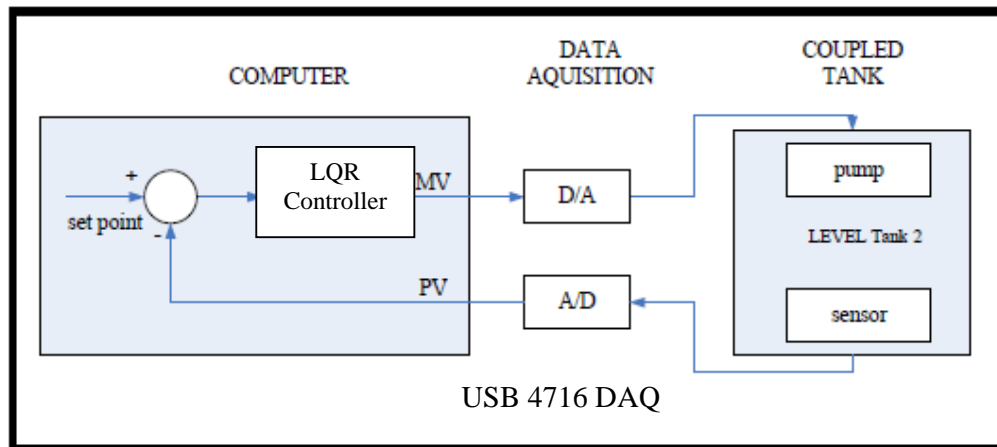


Figure 3.3: Block Diagram of close loop system (Second Order SISO) with LQR controller